Faculty of Engineering

THE EFFECTIVENESS OF ADDITIONAL SEPARATE LANES AS RIGHT TURN AND U-TURN FACILITY AT SIGNALIZED INTERSECTION ON QUEUE PROBABILITY AND DELAY

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THE EFFECTIVENESS OF ADDITIONAL SEPARATE LANES AS RIGHT TURN AND U-TURN FACILITY AT SIGNALIZED INTERSECTION ON QUEUE PROBABILITY AND DELAY

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ABSTRACT

Many arterials are hopelessly congested. In many places, engineers have done as much as they can with conventional improvements. The objectives of the study were to evaluate whether installed additional separate lanes as right turn and U-turn facility at signalized intersection gives any effect to the traffic operation in terms of delay and queue probability on the roadway and also evaluate the impacts that the length (corner clearances) of additional separate lanes between a driveway and a down stream signalized intersection has on the traffic operational performance. The goal is to promote U-turns, with the proper designs, where the additional separate lanes are set at its most desirable length. The literature review indicated that the use of additional separate lanes / taper lanes as right and U-turn is effective in reducing delays as well as queue probability. The analysis of the level of service (LOS) shows that "Jalan Song" additional separate lanes results in a large number of congestion at the signalized intersection and also bottleneck area during peak hours. Those factors lead to the ineffectiveness of the additional separate lanes as right turn and U-turn facility at the Mabel signalized intersection. Using delay time as a measure of effectiveness, it was concluded that the presence of U-turn and right turn of the additional separate lanes did not enhances the operation of the "Jalan Song" arm due to the huge traffic flow during peak hours. The results show that the Level of Service (LOS) is F and the length of the current additional separate lanes is not able to accommodate the huge traffic flow during those peak hours. This is due to the limited length of additional separate lanes before the signalized intersection. The study recommends mainly in providing a over pass or "fly over" to the signalized intersection and to the Mabel Intersection besides increasing the length of the additional separate lanes and increases the cycle length due to the high traffic volumes exceeding the capacity.

ABSTRAK

Banyak jalan utama mengalami kesesakan lalulintas yang teruk. Di kebanyakan tempat, jurutera sivil telah mejalankan pelbagai cara secara konvensional untuk membaikpulihkan jalan raya. Objektif utama bagi pembelajaran ini adalah untuk menganalisis keberkesanan lorong pergerakan ke kanan yang berasingan sebagai belok ke kanan dan pusingan-U di persimpangan Mabel dengan menggunakan kaedah kebangkalian aturan dan kelengahan. Di samping itu, panjang lorong pergerakan ke kanan yang berasingan di persimpangan signal tersebut akan dinilai untuk memastikan keberkesanan operasi trafik di simpang signal itu. Sasaran ini adalah untuk menggalakkan belok ke kanan dan pusingan-U dengan menggunakan rekaan yang sesuai di mana panjang lorong pergerakan ke kanan yang berasingan adalah maximum. Jurnal analisis menunjukkan penggunaan lorong pergerakan ke kanan yang berasingan dan pusingan-U adalah berkesan dalam mengurangkan tundaan serta kebangkalian aturan. Analisis tentang tingkat pelayanan (LOS) menunjukkan lorong pergerakan ke kanan yang berasingan di Jalan Song menyebabkan kesesakan lalulintas di kawasan pendekat dan "bottleneck" serta mengakibatkan ketidakberkesanan lorong pergerakan ke kanan yang berasingan untuk tujuan belok ke kanan dan pusingan-U di persimpangan Mabel. Dengan menggunakan tundaan sebagai ukuran, kesimpulan yang didapati menunjukkan bahawa kewujudan bahagian untuk pusingan-U dan belok ke kanan tidak meningkatkan operasi yang terdapat di jalan tersebut pada masa jam puncak. Keputusan yang didapati daripada survei dan pengiraan menunjukkan bahawa tingkat pelayanan (LOS) adalah F dan panjang lorong pergerakan ke kanan yang sedia ada adalah tidak mencukupi untuk mengisi jumlah kenderaan yang banyak pada waktu jam puncak. Ini adalah disebabkan arus trafik yang banyak pada jam puncak dengan kawasan "bottleneck" dan panjang lorong pergerakan ke kanan yang berasingan yang tidak mencukupi. Pembelajaran ini mencadangkan untuk membina "fly over" di simpang mabel selain memanjangkan lorong pergerakan ke kanan yang berasingan yang sedia ada dan juga memanjangkan masa kitar akibat arus trafik melebihi kapasiti.

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LIST OF SYMBOLS

d = Average overall delay per vehicle (seconds/vehicles),
$d1$ = Uniform delay (seconds/vehicles),
$d2$ = Incremental, or random, delay (seconds/vehicles),
$d3$ = Residual demand delay to account for over-saturation queues that may have existed before the analysis period (seconds/vehicles),
PF = Adjustment factor for the effect of the quality of progression in coordinated systems
C = Traffic signal cycle time (seconds),
g = Effective green time for lane group (seconds),
X = Volume to capacity ratio of lane group,
c = Capacity of lane group (vehicles/hour),
k = Incremental delay factor dependent on signal controller setting (0.50 for pre-timed signals; vary between 0.04 to 0.50 for actuated controllers),
I = Upstream filtering/metering adjustment factor (1.0 for an isolated intersection)
T = Evaluation time (hours),
P = Proportion of vehicles arriving during the green interval,
F_p = Progression adjustment factor.

G = Minimum green time, sec
W = Distance from the curb to the center of the farthest travel lane on the street being crossed or to the nearest pedestrian refuge island is the pedestrian crossing is to be made over two signal cycle.
Y = Change and clearance interval (yellow + all red time), sec
Vp = Flow rate during 15-min analysis period vph
V = Hourly volume vph
PHF = peak hour factor
S = Saturation flow rate for the subject lane group, expressed as a total fro all lanes in the lane group under prevailing conditions vphgpl
So = Ideal saturation flow rate per lane, usually 1900 pcphgpl
N = Number of lanes in lane group
fw = Adjustment factor for lane width
f_{hv} = Adjustment of heavy vehicle factor
fg = Adjustment of grade factors
fp= Adjustment of parking factors
f_{bb} = Adjustment factor for bus blockage
fa = Adjustment factor for area type (fa) is 0.900 for CBDs and 1.00 for all other area
f_{LU} = The lane utilization factor
f_{RT} = Adjustment factor for right turns (left in malaysia) (fRT) is 0.85 For exclusive right (left in malaysia) turn lanes T
f_{LT} = Adjustment factor for left turn (right in malaysia) is 0.95 for exclusive left (right in malaysia) turn with protected phasing
$f_{Rp/Lpb}$= Adjustment for pedestrian/bicycle blockage for left and right turns

C = cycle length
G = effective green time for lane group, (s)
X = v/c ratio or degree of saturation for lane group
T = duration of analysis period, h
k = incremental delay factor that is dependent on controller settings
I = upstream filtering/metering adjustment factor
c = lane group capacity in veh/h
d_A = delay for approach A, sec/veh
d_i = delay for lane group, i (on approach A), sec/veh
v_i = adjusted flow for lane group i, vph
NQ = Total pcu balance from the previous green phase
DS = Degree of Saturation
GR = Green ratio
QL = Queue Length
C - Capacity = (saturated flow) x (green ratio)

CHAPTER 1

INTRODUCTION

1.1 Background

With 2004 population of more than 450,000, Kuching is one of the largest cities in Sarawak and is one of the fastest-growing communities in the State. The growth in Kuching City and other communities to the South and North has had immediate impact on traffic growth in the study area due to their proximity. The increase in population in Kuching city is accompanied by a large number of vehicles and drivers on Sarawak roadway (refer to table 1).

Table 1. Statistic of Increased number of vehicle ownership in Sarawak until 2003 (Sources: Road Transport Department, Sarawak)

TYPES	1999	2000	2001	2002	2003	MEAN
Motorcars	231,234	244,991	263,752	286,696	311,682	
Growth		**13,757**	**18,671**	**286,696**	**311,682**	
		6%	**8%**	**9%**	**9%**	**8%**
Motorcycles	310,852	328,633	343,736	357,751	379,623	
Growth		**17,781**	**15,103**	**14,012**	**21,872**	
		6%	**5%**	**4%**	**6%**	**5.3%**
Taxi	3,881	4,133	4,383	4,575	4,891	
Growth		**6.5%**	**6%**	**4.5%**	**6.9**	**6%**
Bus	2,225	2,259	2,281	2,347	2,390	
Growth		**1.5%**	**1%**	**2.9%**	**1.8%**	**1.8%**
Good Vehicles	35,406	37,447	39,003	40,682	43,037	
Growth		**5.8%**	**4.2%**	**4.3%**	**5.8%**	**5%**
Others	54,742	61,347	67,914	73,674	81,263	
TOTAL	**638,340**	**678,810**	**721,069**	**765,725**	**822,886**	
Growth		**40,470**	**42,259**	**44,656**	**57,161**	
		6.3%	**6.2%**	**6.2%**	**7.5%**	**6.6%**

Many urban and suburban arterials are hopelessly congested. Traffic engineer in many places have done as much as they can with actuated signal, provided multiple left turn and right turn followed by U-turn lanes and other conventional measures. Issues such as these have led to development of the access management technique. As defined by AASHTO, 2000, "access management involves providing (or managing) access to land development while simultaneously preserving the flow of traffic on the surrounding road system in term of safety, capacity, and speed". Sound access management can have a profound impact on highway safety and the ability of roadways to successfully carry traffic. Failure to properly manage access can result in safety concerns as well as lead to diminution of the public's investment in the roadway system. A significant part of access management technique focuses on the treatment of Right-turn followed by U-turn along the roadway. Approaches used to achieve control of right turn, use of U-turn either at or after the intersection, and consolidation of median openings.

Sarawak, especially Kuching increasingly uses of additional separate lanes / taper lanes on multi-lane intersections to manage right turn and U-turn egress maneuver from driveways or side streets. The concept of U-turn with additional separate lanes / taper lanes as Right or U-turn movements is a relatively new approach in Sarawak and has recently been implemented in several locations. The safety gain from such design is due to the decrease in the number of conflicting points at the intersections. According to Stamatiadis N and Clayton A, 2004, there are three ways that a U-turn movement can be completed as illustrated in figure 1:

i. In advance of the intersection

ii. At the intersection

iii. After the intersection

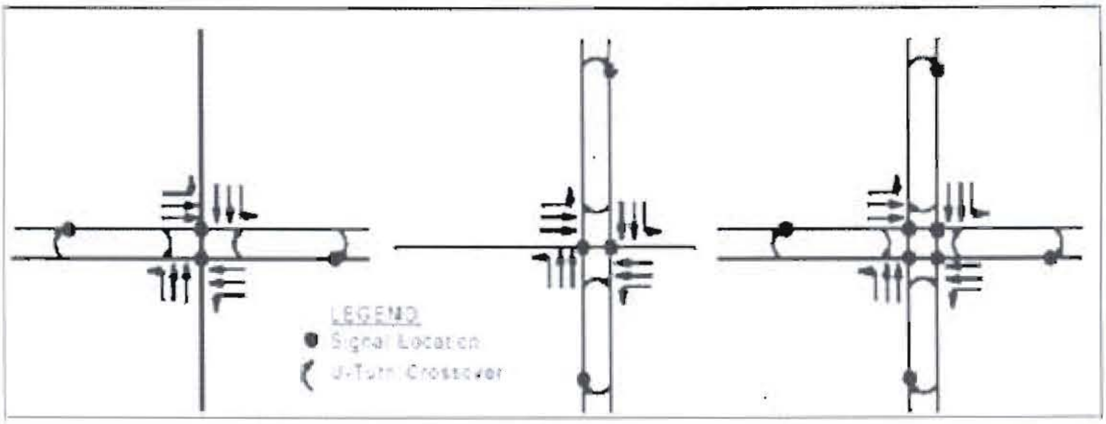

Figure 1 - Configuration of U-turn

Median Opening - After intersection & Median Opening – Before intersection at different state at cases (Typical Median U-turn Crossover Designs)

The most current applications in Kuching involve U-turn at the intersection so this is the type of U-turn that was examined in this project. Moreover, this treatment is associated with additional separate lanes (corner clearances) at a signalized intersection. This treatment requires a protected right turn phase to accommodate right and U-turn at the same time.

1.2 Statement of Problems

A primary goal of intersection design is to limit the severity of potential conflicts among road users. Intersection channelization such as implementation of corner clearances, a geometric design concept used to reduce conflicts, employs such techniques as raised medians or traffic islands with corner clearances to discourage wrong-way turns or other undesirable movements. Engineers also separate conflict points by adding turn lanes and reducing the number of approaches to the intersection. In addition, intersection approaches that cross as close to 90 degrees (right and left turn) or 180 degrees (U-Turn) as practical can minimize the exposure of road users to potential conflicts.

On the other hand, at the intersection. traffic congestion always occurs due to drive maneuver, especially for straight and right direction, and sometimes followed by U-turn maneuver using same lane (only provided one lane for straight, right turn followed by U-turn) during peak hours. The problem occurs because of the following reasons:

i. Limited of corner clearances length.
ii. Too much traffic on the roadway.
iii. Residential areas which located along 'Jalan Laksamana Cheng Ho to Batu Kawa'.
iv. Attitude and behavior of road users.

v. Increase of vehicles on the road every year.

vi. Working hour and off hour at the shophouses along the area of 'Jalan Laksamana Cheng Ho to Batu Kawa'.

Therefore, we need to look carefully in those matters above and carry out research for Effectiveness of Additional Separate Lanes as Right turn and U-turn Facility as Signalized Intersection on Queue Probability and Delay. Ramps junction or corner clearance is the distance between an intersection and the nearest driveway. Currently, signalized intersection in Sarawak, especially in Kuching city was provided with additional separate lanes to decrease the number of conflict point. Actually, this system is not popular as design implementation in intersection because as usual, the additional separate lanes installed at freeway and interchange to clearing right turn or left turn. Sometimes, the additional separate lanes used in median opening for U-turn before and after approach to intersection. Furthermore, Sarawak in recently years, has been implement the new approach which was implement the ramps junction at intersection as U-turn facility to reduce capacity problem (refer to figure 2). Unfortunately, inadequate clearances (length) can result in traffic operation, safety and capacity problems. These problems can be caused by blocked driveway ingress and egress, insufficient weaving distances, and backup from downstream driveway into an intersection as possible to reduce conflict from overlapping movement.

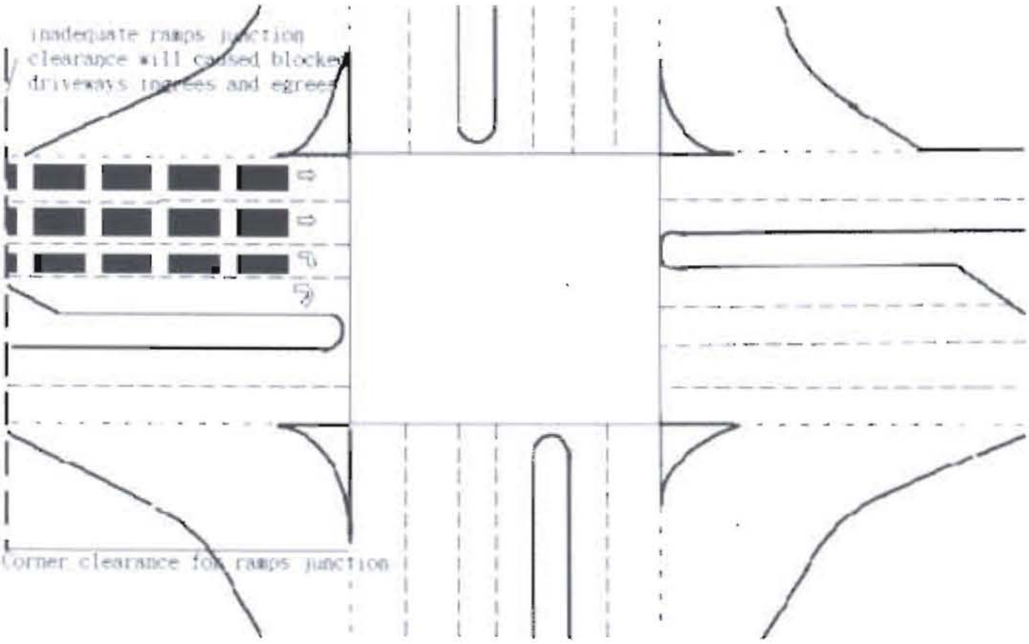

Figure 2 - Design of Additional Separate Lanes as U-Turn Facility at Signalized Intersection (Modified from Design Memorandum No 07-05, Subject: HD 100, Access Management Guidance, AASTHO, 2000)

1.3 Objectives of the Study

The primary objectives for this study are to:

i. Evaluate whether installed additional separate lanes as right turn and U-turn facility at signalized intersection gives any effect to the traffic operation, delay, and queue probability on the roadway.

ii. Evaluate the impacts that the length (corner clearances) of additional separate lanes between a driveway and a down stream signalized intersection has on traffic operational performance. The goal is to promote U-turns, with the proper designs, where the ramps junction is set at its most desirable length.

1.4 Scope of Study

This study only works on evaluation of implementation of additional separate lanes as right turn and U-turn facility at signalized intersection. On the other hand, Study the traffic operation, including queue probability, and delay of right turn and U-turn facility at signalized intersection will be conducted as well. Furthermore, Level of Services (LOS) at the U-turn facility at signalized intersection will be discussed based on LOS speed criteria and LOS capacity criteria.

1.5 Profile of Study Area

The study area is at Mabel intersection which covers Jalan Song, Jalan Laksamana Cheng Ho and Jalan Tun Jugah. The area here is of areas of residential, commercial or industrial developments of sufficient concentration. They constitute or are characteristic of a city which necessitates, for safety reasons, reduced highway speed limits to 70 kph or less, excluding interstate systems.

Along Jalan Tun Jugah to the airport, a lot of shophouses has been constructed. Heavy traffic occurs often during morning peak hour and afternoon peak hour. Along Jalan Laksamana Cheng Ho, there have a lot of residential areas and if we see further down the road we have a lot of commercialized shop houses situated at the end road of "Jalan Laksamana Cheng Ho". This road also contributes to the heavy traffic during peak hours. Next, we have "Jalan Song". Heavy traffic also occurs during peak hours at this road because of the high demand of work load can be found in 'Tabuan Jaya', "Jalan Song", BDC area, Samarahan area and also Pending area. "Jalan Song" link to those places. Because of such situation, traffic jam always occurs during peak hours.

Mabel intersection (Figure 3) is currently catering a very high demand of traffic users because it links to most of the working area around Kuching, Samarahan, 'Batu Kawa' and Airport. The Mabel intersection is illustrated as below:

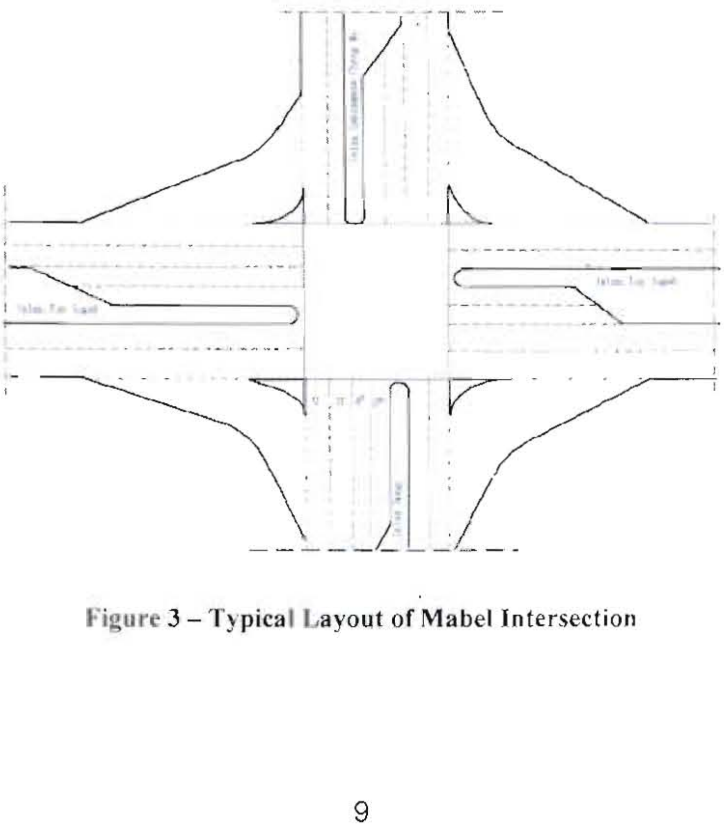

Figure 3 – Typical Layout of Mabel Intersection